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WOODS HOLE OCEANOGRAPHIC INSTITUTION

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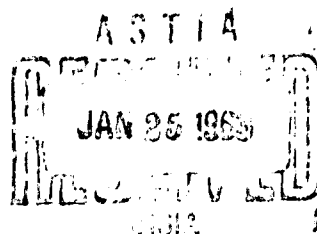
Reference No. 62-41

DEEP SUBMERGENCE RESEARCH

conducted during the period
1 November 1961 - 31 October 1962

Prepared under Contract Nonr-3484(00)

WOODS HOLE, MASSACHUSETTS



Woods Hole Oceanographic Institution

Woods Hole, Massachusetts

Reference No. 62-41

Deep Submergence Research

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Submitted to Undersea Programs
Office of Naval Research

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November 1962

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Paul M. Fye, Director

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Abstract

This is the first Annual Summary Report of work performed under Contract Nonr 3484(00), which contract work commenced in October 1961. A deep sea research group was formed. This group was organized to monitor and later to operate the ALUMINAUT. Although the ALUMINAUT is under construction with a planned delivery date of early 1964, it is not now clear whether it will be leased by Woods Hole Oceanographic Institution or some other organization. The program is still being followed but not in as much detail as originally planned.

A specification was prepared and proposals solicited from industry in May 1962 to design and construct a 6,000 foot research vehicle. Competitive bids were received and the vehicle contract was awarded to General Mills on 4 September 1962. The pressure hull structural analysis and the associated engineering details, the propulsion, and the trim and buoyancy systems have been the major problems studied. A hydrodynamic study is being conducted with a 1/12 scale model at MIT. A scanning sonar set proposal has been solicited, bids received and a contract for manufacture of the set is awaiting ONR approval. A proposal has been received for a mechanical arm.

The future activity planned includes the engineering supervision and drawing approval of the design. The manufacture of the vehicle will be closely inspected. Additional instrumentation will be specified and ordered. Items will be designed for ALUMINAUT pressures to provide interchangeability. More personnel will be added to the staff as required. Stability and hydrodynamic characteristics will be studied and detailed structural analysis will be completed. Technical reports will be prepared on appropriate phases of this activity. The ALUMINAUT program will continue to be monitored to the extent necessary. The handling and towing problems will be studied.

Reports

The following technical reports have been prepared under this contract and completed during this period:

WHOI Ref. No. 62-32.

Strength of the ALUMINAUT Hull
by Joseph B. Walsh
dated April 1962 (Unclassified).

WHOI Technical Memorandum No. TM-DS-5.

Analysis of Details of ALUMINAUT Pressure
Hull Joint by J.W. Mavor, Jr. and J.B. Walsh
dated January 31, 1962 (Unclassified).

WHOI Technical Memorandum No. TM-DS-7.

Structural and Hydrodynamic Analysis
Subjects for Research by J.W. Mavor, Jr.
dated March 16, 1962 (Unclassified).

WHOI Technical Memorandum No. TM-DS-8.

Considerations in the Design of Instruments
for Use with ALUMINAUT by J.W. Mavor, Jr.
dated March 16, 1962 (Unclassified).

Introduction

This is the first Annual Summary Report for the work conducted under Contract Nonr 3484(00) for the period 1 November 1961 through 31 October 1962. The scope of this contract covers the procurement and operation of a manned deep submergence vehicle(s) for use as an oceanographic tool in support of the research conducted at this Institution.

During this period a group of persons were formally organized to pursue this problem from several points of views; the ALUMINAUT program was monitored; and a contract for a new vehicle for operation to a depth of 6,000 feet, was negotiated and signed with General Mills, Inc. on 4 September 1962. This latter vehicle has presented many interesting problems relating to structure, stability, hydrodynamics, observation capabilities, and instrumentation. This is the major continuing effort. The ALUMINAUT program will continue to be monitored. It appears that ALUMINAUT will now probably be completed some time between early and mid-1964. "ALVIN" (the 6,000 foot craft has been tentatively dubbed "ALVIN") is scheduled for delivery in the late summer of 1963.

Phase I The ALUMINAUT (Figure 1 & 2)

Background

The initial funded activity for the purpose of acquiring this vehicle from Reynolds Metals Company to be used for scientific research was commenced under another contract, Nonr 1367, and the work was reported under that Contract (See WHOI Ref. No. 61-16 and Ref. No. 62-14). Work on this project applicable to Contract Nonr 3484 was commenced in October 1961. Personnel already active at that time were Mr. Allyn Vine, Mr. James Mavor, Jr., Dr. Joseph Walsh and Mr. William Rainnie. In January 1962, Dr. Earl Hays joined this group and was appointed Project Director. Subsequently, separate office space was acquired and a secretary, Mrs. Mabel Reese, was added to the staff. In May 1962, Mr. Oliver Johnsrud was added to assist in providing resident inspection at the place of manufacture and assembly of the ALUMINAUT and "ALVIN".

Frequent visits were made to Electric Boat Division of General Dynamics (EB) by project personnel, to learn as much about the vehicle design details as practical, and to recommend changes to improve its capabilities for its intended use as a scientific instrument, and to improve, where possible, its operational safety and versatility.

Structural Analysis

An extensive independent theoretical structural analysis and model test program was conducted and continues at reduced pace. The

structural analysis is contained in WHOI Reference No. 62-32 and WHOI No. TM-DS-5 listed at the beginning of this report.

Model Testing

A 1/16 scale model (Figure 3 & 4) has been manufactured and is being instrumented with strain gauges for pressure testing in the WHOI tank. This test will be conducted in the near future. Although it is possible that the ALUMINAUT will never be used at WHOI, this model was so near completion when negotiations for leasing bogged down that it was decided to complete this phase of the test program on the basis that data gained therefrom would contribute to the general knowledge in the area of shell theory and structural strength problems. A separate report will be made on the results of this testing.

A 1/6 scale model, material for which had been ordered and was on hand, had not been carried far enough along to justify completing it at this time. Therefore, this phase of the test program was postponed. It was originally intended that this model would duplicate more completely the full scale hull than any previous or planned model testing had done or would do. In particular, the regions of stress concentration in way of the flanged joint, which analysis has shown to appear critical, were to have been examined. This, along with the 1/16 scale model above and EB's 1/16 scale models would establish both the validity of the structural analysis conducted at WHOI and elsewhere and establish a reasonably high level of confidence in the collapse mode and depth, as well as the safe operating depth of ALUMINAUT.

Other Programs

Other planned programs associated specifically with this vehicle have been curtailed or postponed. These included a full scale mock-up of one half of the submarine, stress corrosion problems of 7079 T6 aluminum alloy, corrosion prevention, hydrodynamic characteristics, fatigue problems, inspection during construction, and procurement of instrumentation unique to ALUMINAUT. In this latter regard, where practical, weight and cost-wise, instrumentation, such as sonar, mechanical arm, etc., for "ALVIN" is being procured for operation to the depths of ALUMINAUT, in order to provide a measure of interchangeability, should the latter become available at a later date for use at WHOI.

Status of ALUMINAUT

WHOI has spent considerable time monitoring the design and construction of ALUMINAUT and cooperating with Reynolds and EB. General opinion to the contrary notwithstanding, the construction of this vessel is proceeding, although at a slower rate than originally scheduled. This schedule change has been caused principally by forming problems associated with achievement of sufficient work hardening in pieces of such great thickness and large overall size. Many, if not all of these difficulties have been resolved and several hull cylinders

(Figure 5) and one hemisphere have been forged and rough machined. In addition, many of the component parts have been completed and delivered to Electric Boat. The current construction completion date is early 1964. An extensive deep water testing program will be carried out after completion, so that it is estimated that its availability for scientific use will be in the spring of 1964 or later.

Property Accumulated for Use on ALUMINAUT

We ordered as spares one (1) propulsion (5 HP) and two (2) steering and diving (1/4 HP) motors concurrently with Electric Boat in order to obtain a significant reduction in price, and because no spares for these motors were intended to be supplied with the craft. These are now on hand. If not required for ALUMINAUT, they will be useful for other projects since they are designed for submerged pressure operation in oil. One such use might be as an underwater drill.

We have acquired a Navy Surplus P5M rubber dock (Figure 6), which appeared at the time to offer an excellent portable berthing facility at WHOI for the relatively fragile sides of the ALUMINAUT. This is now in storage, but will be used in experiments to be made for solving the unusual handling and berthing problems of underwater vehicles.

Phase II The "ALVIN" (Fig. 7 concept, 8 cross section)

Background

When it became clear early in April 1962 that contractual difficulties with the ALUMINAUT might well prevent the acquisition of a manned deep sea capability at WHOI in the near future, an informal survey of industry interest in designing and building such craft was conducted and an assessment of the "state-of-the-art", including an estimated cost, was made. Many discussions were held and the following rationale was set forth as goals to achieve:

"Woods Hole Oceanographic Institution wishes to carry out a scientific program based on the use of deep submersibles. The uses in the fields of biology, geology, hydrography and acoustics have been amply discussed and details will not be brought up here. The purpose of this writing is to explain why we chose the particular program presented.

The depth area curve of the oceans is such that there are two breaking points for area versus depth; one covers the shelves (100 fathoms), (Figure 9), and the other all except the deep trenches (3,000 fms.). However, the shallow break does not seem to us to be a depth to which a submersible should be limited. This is based upon the now readily obtainable depths with

reasonably standard engineering practices, the particular areas available as function of depth, and the fact that operational costs will be reasonably independent of depth once the craft size is determined.

We propose to obtain as soon as possible a craft with capabilities for two people and a six thousand foot working depth. General and specific requirements for this craft are in the following table:

Description of Proposed Vehicle for Phase I

	<u>Minimum</u>	<u>Desired</u>
Operating Depth	4,000 ft.	6,000 ft.
Factor of Safety	1.4	1.5
<u>Speeds and Endurance</u>	Maximum 6 knots for 5 min.ea.hr. Cruising 3 knots for 8 hr.	
Number of Persons	2	3
Weight in Air	6 Tons	10 Tons
Pay load, instruments	1,000 lbs.	1,500 lbs.
Pay load power capacity	1 KW for 8 hrs.	2 KW - 8 hrs.
Normal Ballast	Lose or gain at operating depth	
Emergency Ballast	Normal ballast + 5% submergence displacement	
Batteries	External and droppable	
Maneuverability	Maximum possible within other parameters	
Cost, craft less instruments	\$500,000	
Cost, instrumentation	\$150,000	
Design and Delivery Time	1 year	
Handling Requirements	Equivalent to a ship's lifeboat	

Engineering studies have been made and reasonably firm prices exist for this type of craft. In addition, we propose to work closely with the Navy and/or others in the design of a future craft which will have a working depth of 20,000 feet. We feel that the operational experience we gain with the shallower craft will greatly influence the design of the deep one in terms of maneuverability, speed and range requirements, appendages and tender problems, but not in fundamental structure problems.

We choose the 6,000 foot depth for the following reasons, comparing a 4,000 foot to 6,000 foot limit.

<u>4,000</u>	<u>6,000</u>
Barely S/V minimum	Well through S/V minimum
<u>Can reach</u>	<u>Can reach</u>
Shelf, some slope, Blake Plateau, Part TOTO, Part Bermuda, a few sea mounts	Shelf, more of slope, Blake Plateau, Most TOTO, Most Bermuda area, tops many sea mounts.

Cameras	90#
Power Conversion	60
Miscellaneous recorders and instruments	<u>460</u>
Total Pay load	1,200#

Power for science - 18 kwh minimum
 Weight in Air - 10 long tons
 Number of windows - 5 (4 in nose, 1 in hatch)
 Hull materials permitted - HY120 Steel or below, aluminum
 or titanium
 Navigation equipment - Gyro compass, magnetic compass,
 speed indicator, depth gauges
 External Buoyancy Material - Permitted but of approved
 material
 Fore and aft trim capability - ± 30
 Batteries - Lead-acid type
 Through hull electrical leads - 120-10 amp, 5 of which are
 coaxial
 Minimum Inside Dimension of the Pressure Hull - 6 1/2 feet
 Access hatch - 20" minimum
 Major Safety Features - Batteries and fixed ballast droppable,
 pressure sphere separable from
 rest of vehicle
 Evaluation - Preliminary trial period at 100 feet; unmanned
 dive to 7,200 feet; manned dive
 to 6,000 feet
 Model testing - Two 1/3 scale collapse models; one 1/2 scale
 fatigue test model

Contract Award

The Bureau of Ships was interested and participated in this project. Their assistance in the evaluation of the bids and preparation of the special provisions and specifications for the safety of the craft which were invoked in the final contract, was of vital importance to the project. After lengthy negotiations required to define the goals and share of the risks involved, a fixed price design and construction contract was signed with General Mills Electronics Group on September 4, 1962. Additional features added during the negotiations that may be of interest were:

1. The inclusion of an additional pressure hull to insure that a manufacturing or handling mistake did not delay the delivery unreasonably. This also provided an extra hull for full scale test purposes.
2. A pressure tank is being constructed at Southwest Research Institute suitable for testing the full scale pressure hulls; therefore, a tank test was substituted in lieu of the "unmanned dive" (Note: a third full scale hull, to be cycled and carried to collapse has been substituted for the models to insure data that most nearly duplicate the hull used in the vehicle).

Pressure Hull (Figure 11)

The pressure hull is, of course, one of the most important and also long lead-time items in the design and manufacture of such a vehicle. It was therefore the first order of business. The present state-of-the-art seemed to indicate that the best manufacturing technique would be to spin two hemispheres of HY100 steel, weld these together at the equator and then weld in forged, tapered inserts in the way of the hatch, windows and other penetrations. Several very helpful conferences have been held at Bureau of Ships on this subject. The design has proceeded in this direction. To optimize the design from a weight and stress standpoint, a detailed analytical study of this problem is currently being carried out by General Mills and WHOI. The pressure hulls have in the meantime been ordered. They will be spun by Lukens Steel, Coatesville, Pa., and fabricated by Hahn & Clay, Houston, Texas.

Surface Stability and Drag

One of the criteria for successful use of this craft is the ability to safely leave and enter it on the surface in waves at least 5 feet high. WHOI, therefore, is undertaking a 1/12 model scale testing program soon to be conducted in the Ship Model Towing Tank at Massachusetts Institute of Technology. The model has been made to drawings furnished by General Mills. Test results and a report should be available in the very near future.

Upon completion of the surface tests, it is intended to study the towing characteristics, free ascent behavior, and obtain data on the submerged drag using this model. Additionally, the surface behavior relative to a surface ship should be an interesting study in order to arrive at some conclusion regarding the handling problems at sea.

Mock-up (Figure 12)

WHOI has made a full scale mock-up of the pressure sphere out of fibreglas for a very reasonable cost, using the hemisphere from ALUMINAUT as a mold. This mock-up was deemed desirable and necessary to aid in the decisions concerned with:

1. Window location
2. Access
3. Internal arrangement
4. Control and instrument location

General Mills has mocked up a full scale model of the conning tower to check hatch clearance, space available and access.

Propulsion System

The propulsion system proposed is electro-hydraulic. It was intended that the electric motors would run in oil, but preliminary test data indicates that the high speed, light-weight, aircraft type dc motors may not be able to perform satisfactorily under these conditions. Further tests are planned and alternate methods such as 3 phase AC motors (brushless), or mechanical gas-oil seals, and low speed dc motors are being studied. Although this problem is troublesome, it is believed a satisfactory solution will soon be in hand.

Buoyancy Material

The external buoyancy material has been under study and some small experiments have been performed. A NOTS, China Lake report on this subject has been made available and further extensive experimentation may not be necessary for this operating depth.

Inspection

WHOI has employed a full-time engineer, Mr. Oliver Johnsrud, to serve as resident representative during the construction phase. He will monitor all of the important steps in this process, assisted as necessary by the rest of the staff. This activity will tend to insure that the high standards set forth in the specifications are in fact adhered to. It may become necessary to request some assistance from the INSMAT, Dallas, during the hull fabrication phase at Hahn & Clay, but this matter has not been decided definitely in the absence of a detailed fabrication schedule. Welder qualification at Hahn & Clay is in the same category.

Instrumentation

Scanning Sonar - With the close cooperation of Messrs. Robert Waldie and Arthur Roshon, Naval Electronics Laboratory, and Dr. Chester McKinney and Mr. Reuben Wallace of the Defense Research Laboratory, University of Texas, the Specification originally prepared for the ALUMINAUT was modified to save weight and power. This specification was sent with an RFQ to eight (8) bidders on 11 September 1962, and four proposals were received by the closing date, 10 October. The bids were evaluated and Straza Industries was chosen to be the contractor, based upon a sound technical proposal and low fixed price bid. Approval to proceed with the contract is being requested from Office of Naval Research, Boston.

Basic characteristics are as follows:

Mode of operation	CTFM
Max. Range	800 yards
Frequency (Sawtooth downswept)	90 - 70 kcs
Max. power	500 watts

Max. weight	225#
Scanning mode	Horizontal with adjustable sector scan.
Transmitter Beam Pattern	Vertical 16°, Horizontal 60°
Receiver Beam Pattern	Vertical 15°, Horizontal 2°
	No. of channels 40
Frequency Analyzer	Bandwidth each 50 cps
	Bandwidth total 2,000 cps
	Bandwidth analyzed 500-2,500 cps
Presentation	Single P.P.I.
	Aural range information
	Second Sweep Mixing
Test Pressure for External Components	10,000 psi

Mechanical Arm - A proposal has been requested from General Mills to provide the mechanical arm. The technical details and price are under preparation.

Miscellaneous - A 16 mm movie camera and Polaroid Land Camera have been purchased for the purpose of taking pictures of the significant steps in the fabrication and assembly of the vehicle. These cameras will be used later for underwater photography from inside the sphere and other appropriate photographs. Work is being done on navigation systems, fathometer, underwater telephone, power conversion units, recording equipment, lights and an external camera. These items will be ordered in the next several months.

Future Program

Under this contract an active deep sea research group has been organized and will be added to as appropriate in the near future. Tasks ahead include but are not limited to the following:

1. Conducting structural analysis and tests.
2. Performing engineering supervision and drawing approval for "ALVIN".
3. Conducting inspection of manufacture and assembly of, first the "ALVIN" and, secondarily, the ALUMINAUT.
4. Performing hydrodynamic and stability tests.
5. Specifying requirements and soliciting proposals for the instrumentation.
6. Assembling additional personnel
7. Preparing operational and safety procedures.
8. Assisting and participating in the evaluation trials of "ALVIN", including the shallow water performance, the testing at SRI, and the deep manned dive.
9. Preparing technical reports on specific phases of the activity listed as appropriate.

10. Monitoring the ALUMINAUT program to the extent necessary.
11. Studying the handling problems of this kind of vehicle.

Personnel

The operational personnel for this project are being actively recruited. It is presently planned to obtain a second pilot, engineer and electronic technician in the near future.

Visitors

A total of over 200 persons visited personnel on this project to discuss submarines and equipments during the past year. Being so numerous, these will not be listed by name, but included persons from government activities, foreign nations, other laboratories, industry and consultants.

Project Personnel

Dr. Earl E. Hays, Physicist and Project Director
Mr. Oliver N. Johnsrud, Engineer
Prof. James W. Mavor, Jr., Research Associate in Applied Physics and
Chief Structural Engineer
Mr. William O. Rainnie, Jr., Project Coordinator and Prospective
Chief Pilot
Mrs. Mabel M. Reese, Secretary
Dr. Joseph B. Walsh, Theoretical Mechanical Engineer

Half Time

Mr. Allyn C. Vine, Physical Oceanographer

Part Time

Mr. Howard A. Gaberson, Mechanical Engineering Consultant
Mr. Michael C. Kelly, Summer Student
Mr. Jess H. Stanbrough, Technical Assistant to the Director

APPENDIX A

Presentations, Meetings and Visits

Personnel of the Deep Submergence Group have participated in many meetings and made several presentations concerning the subject matter of their major interest. Meetings attended have been as follows:

National Academy of Science, Materials Advisory Board,
Sub Panel on Deep Diving Submarines
Underwater Acoustic Symposium
Fourth Conference on the Naval Minefield
Society of Experimental Stress Analysis
Society of Naval Architects and Marine Engineers
Instrument Society of America
American Society of Limnology and Oceanography
Pacific Ocean Conference
Institute of Aerospace Sciences

Presentations have been made as follows:

Submarine Force, Atlantic Fleet Informal Monthly Meeting
Briefing to the Oceanographer of the Navy
Com Carrier Division Commander and Staff
Several Groups of Visiting Students
WHOI Journal Club
MIT Lecture Series
Massachusetts Society of Professional Engineers
Visiting ONR Reserve Officers
Navy R & D Symposium at Seattle
Worcester Polytechnic Institute, ME Seminar
Northeastern University, SAME

Visits have been made by project personnel to the following activities during this period:

Bureau of Ships
Bureau of Naval Weapons
Atlantic Missile Range
Naval Electronics Laboratory
Electric Boat Division of General Dynamics, Groton, Conn.
Naval Ordnance Test Station, China Lake
Naval Ordnance Laboratory
Naval Research Laboratory
Submarine Base, New London, Conn.
Applied Physics Laboratory, U. of Washington, Seattle
General Mills, Inc., Minneapolis, Minn.
Reynolds Metals, Richmond, Virginia

Ladish Company, Milwaukee, Wisconsin
Portsmouth Naval Shipyard
Hughes Aircraft Co., Fullerton, Cal.
Massachusetts Institute of Technology
Northeastern University
David Taylor Model Basin
National Academy of Sciences
Arnold Green Testing Laboratory, Natick, Mass.
Programmed and Remote Systems, Minneapolis, Minn.
Naval Underwater Sound Laboratory
Com Sub PAC
Com Sub LANT
Lessells & Associates, Boston



Figure 1 THE ALUMINAUT, AN ARTIST'S CONCEPTION (Courtesy Reynolds International)

ALUMINAUT - DEEP DIVING OCEANOGRAPHIC RESEARCH SUBMARINE

DESIGN DATA:

OPERATING DEPTH	15000 FT.
RANGE	80 MILES
CRUISING SPEED	3.8 KNOTS
CREW	PILOT AND 2 SCIENTISTS
PROPULSION	5 HP VERTICAL 10 HP TWIN SCREW HORIZONTA
POWER SOURCE	4-77 CELL SILVER-ZINC BATTERIES 2600 AMP-HOURS TOTAL
PORTS	FOUR IN BOW
DISPLACEMENT	150,000 LBS.
DIMENSIONS	LOA - 51 FT., I.D. - 7 FT., O.D. - 8 FT.
CONSTRUCTION	11 - FORGED ALUMINUM ALLOY CYLINDERS 6 1/2 IN. THICK 2 - FORGED " " HEMISPHERES
MATERIAL	7079-T6 ALUMINUM ALLOY - 0.2% OFFSET YIELD 60,000 PSI
EQUIPMENT	MECHANICAL ARMS UNDERWATER TELEVISION SONAR UNDERWATER TELEPHONE LIGHTS

Figure 2 DESIGN CHARACTERISTICS OF ALUMINAUT

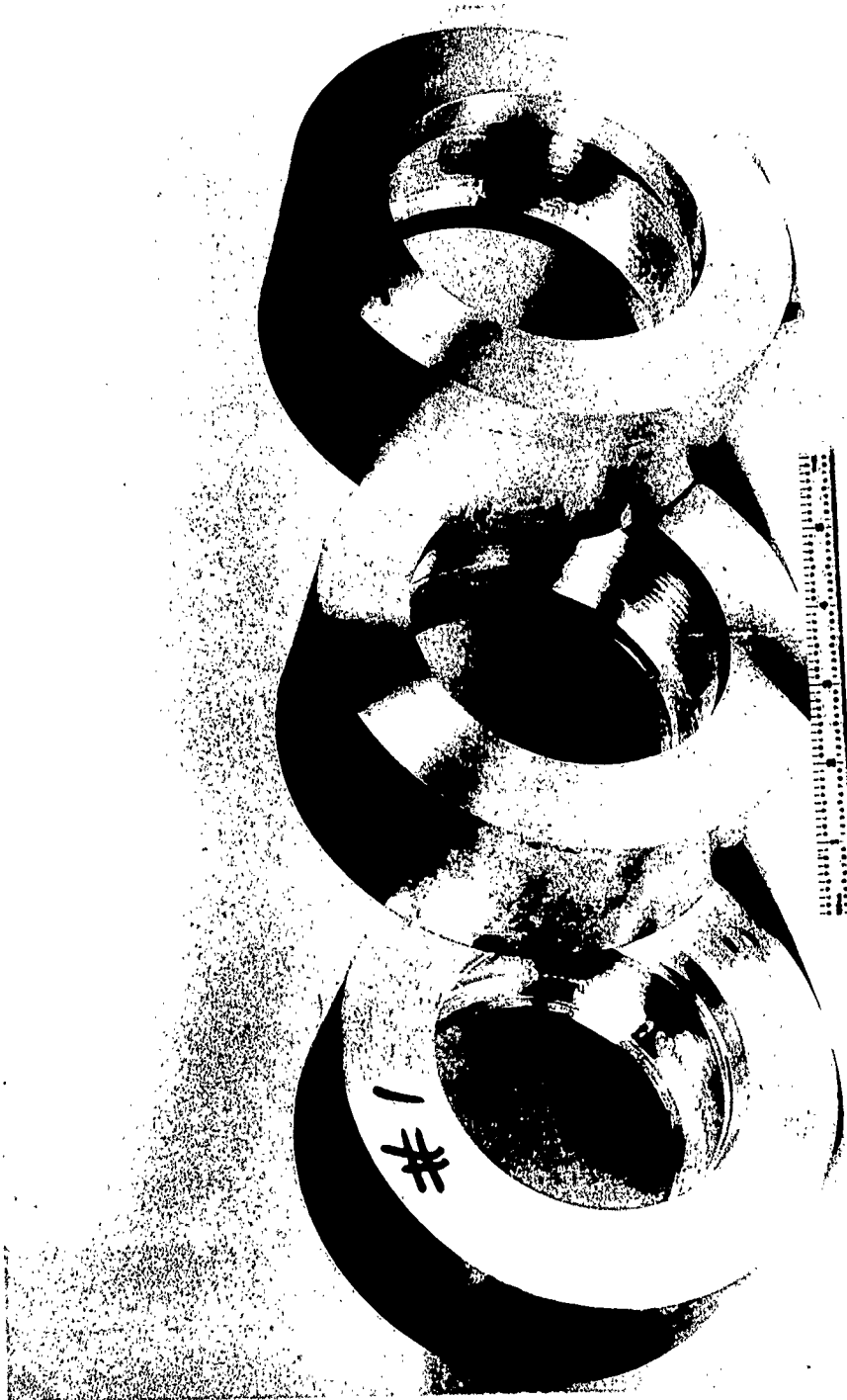


Figure 3 CYLINDRICAL SECTIONS OF WHOI 1/16 SCALE ALUMINAUT
STRUCTURAL MODEL

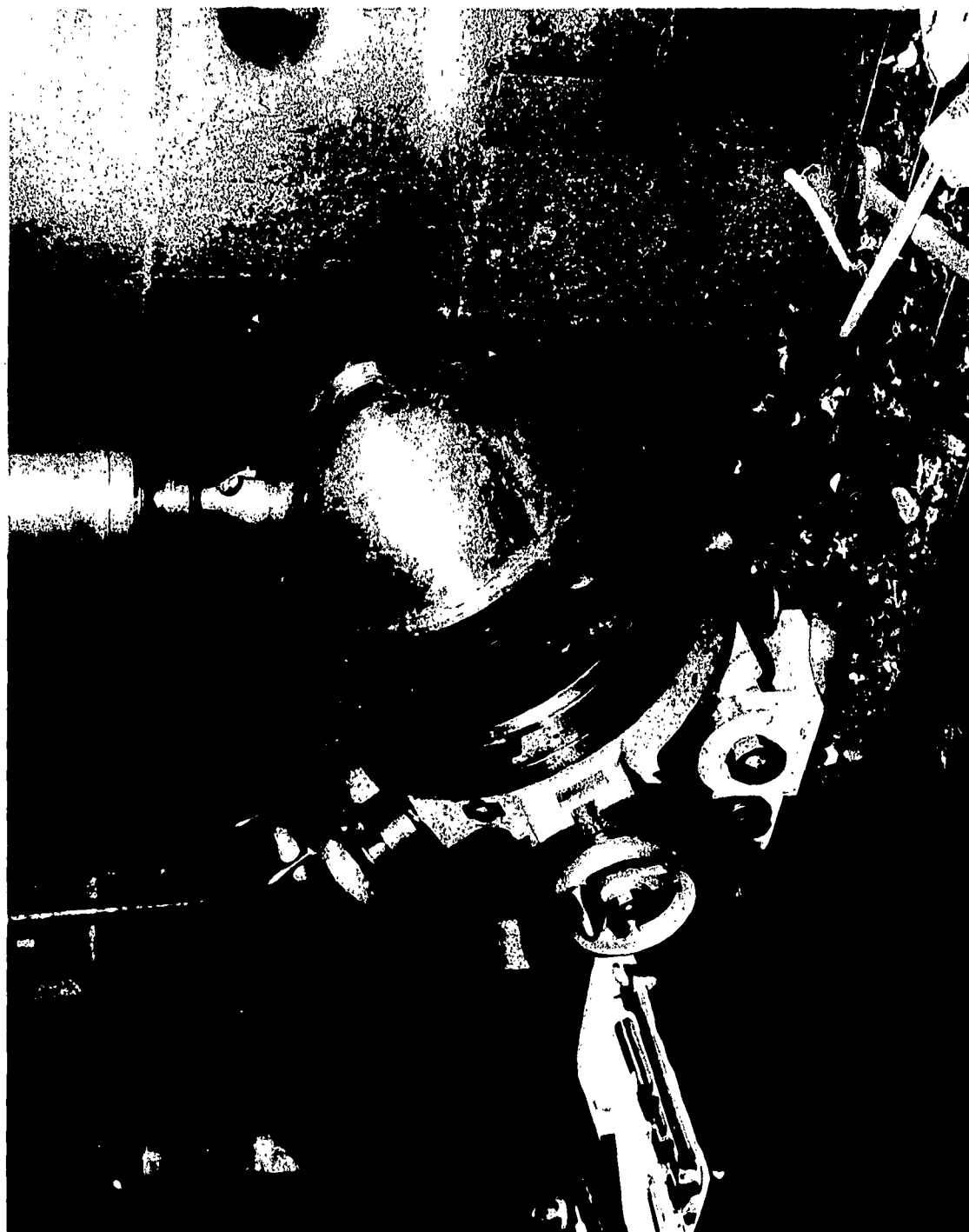


Figure 4 HEMISPHERICAL HEAD OF WHOI 1/16 SCALE ALUMINAUT
STRUCTURAL MODEL



Figure 5 PROTOTYPE FULL SIZE CYLINDRICAL HULL SECTION OF
THE ALUMINAUT (Courtesy of Ladish Co.)

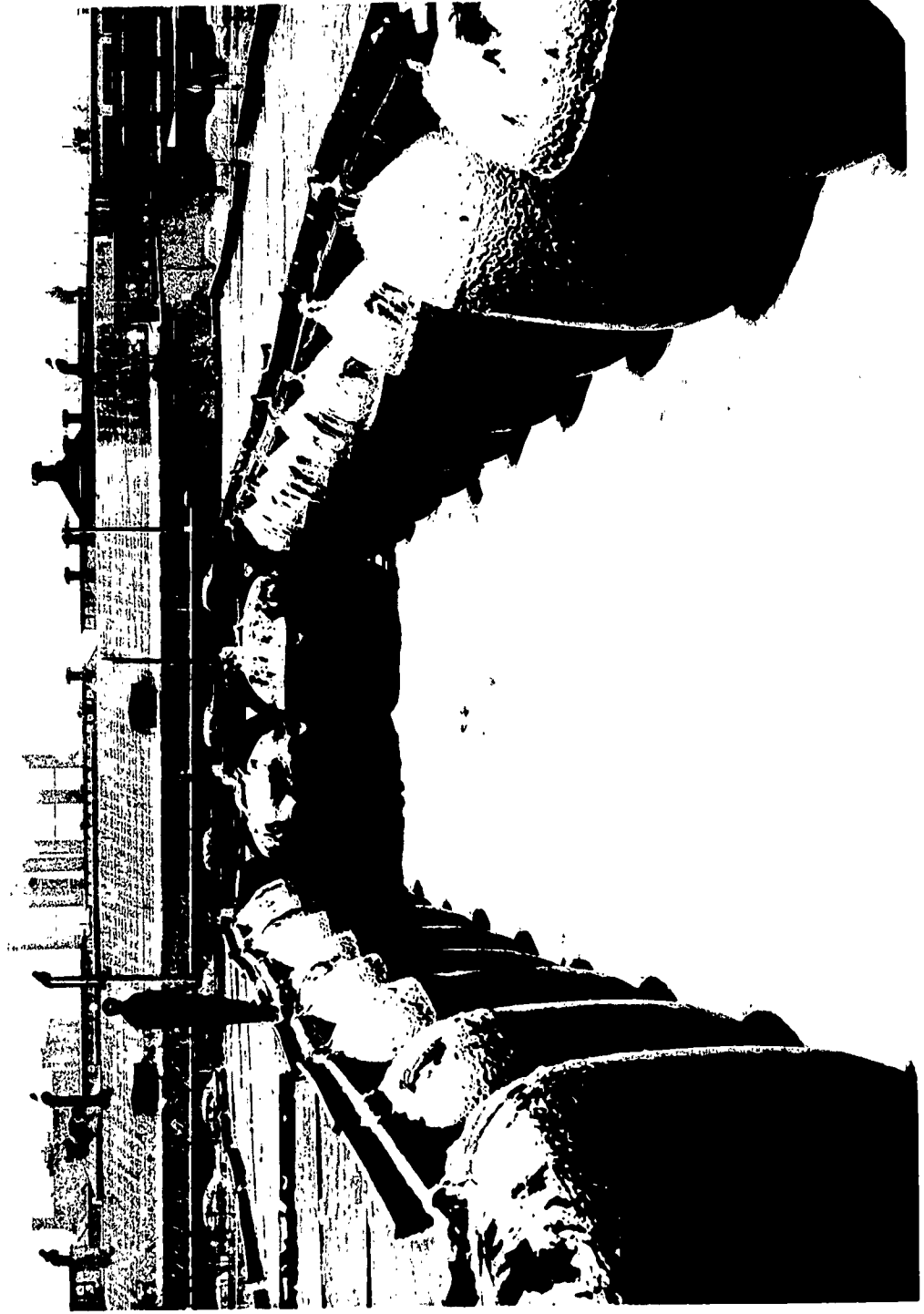
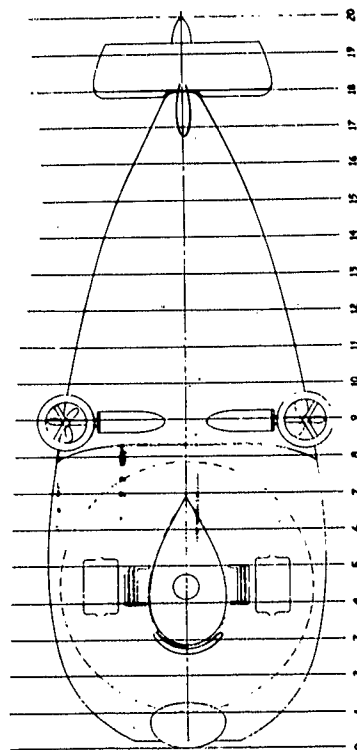


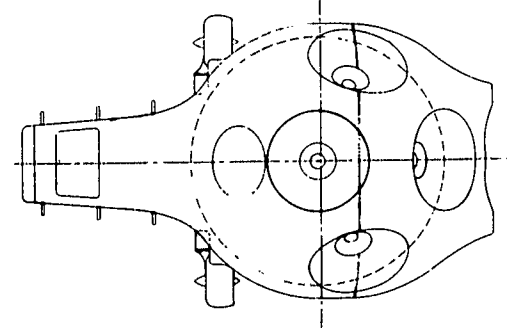
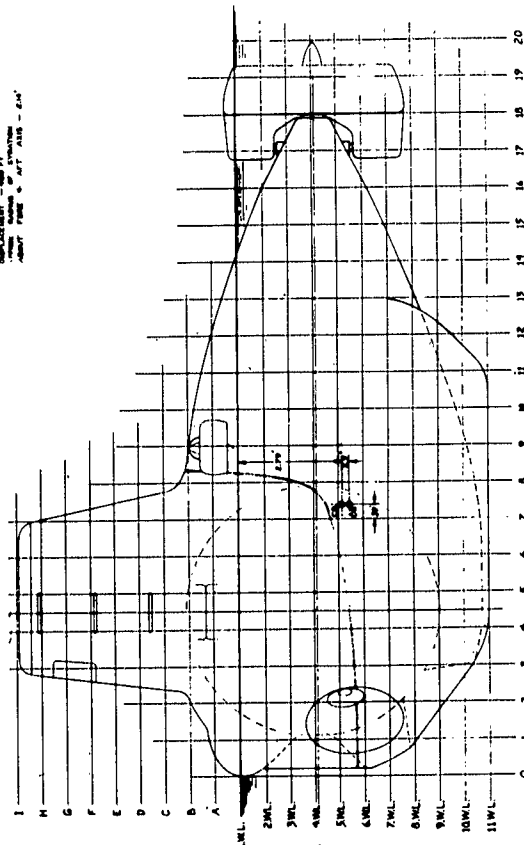
Figure 6 P5M RUBBER U-DOCK



Figure 7 6,000 FOOT RESEARCH SUBMARINE "ALVIN", AN ARTIST'S
CONCEPT (Courtesy of General Mills, Inc.)



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Figure 8 "ALVIN" CROSS SECTION

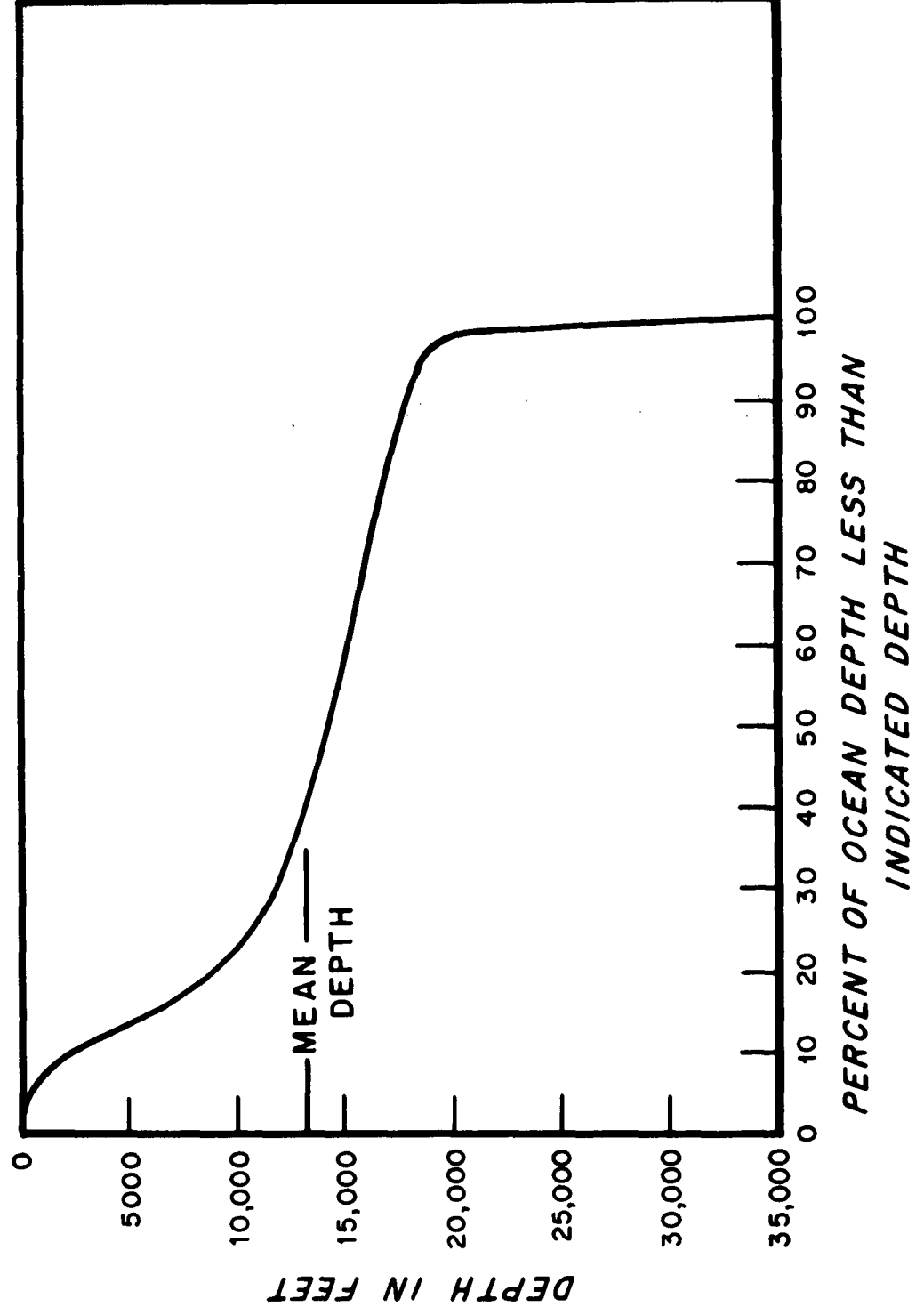


Figure 9 DEPTH AREA CURVE FOR THE OCEANS IN PERCENT

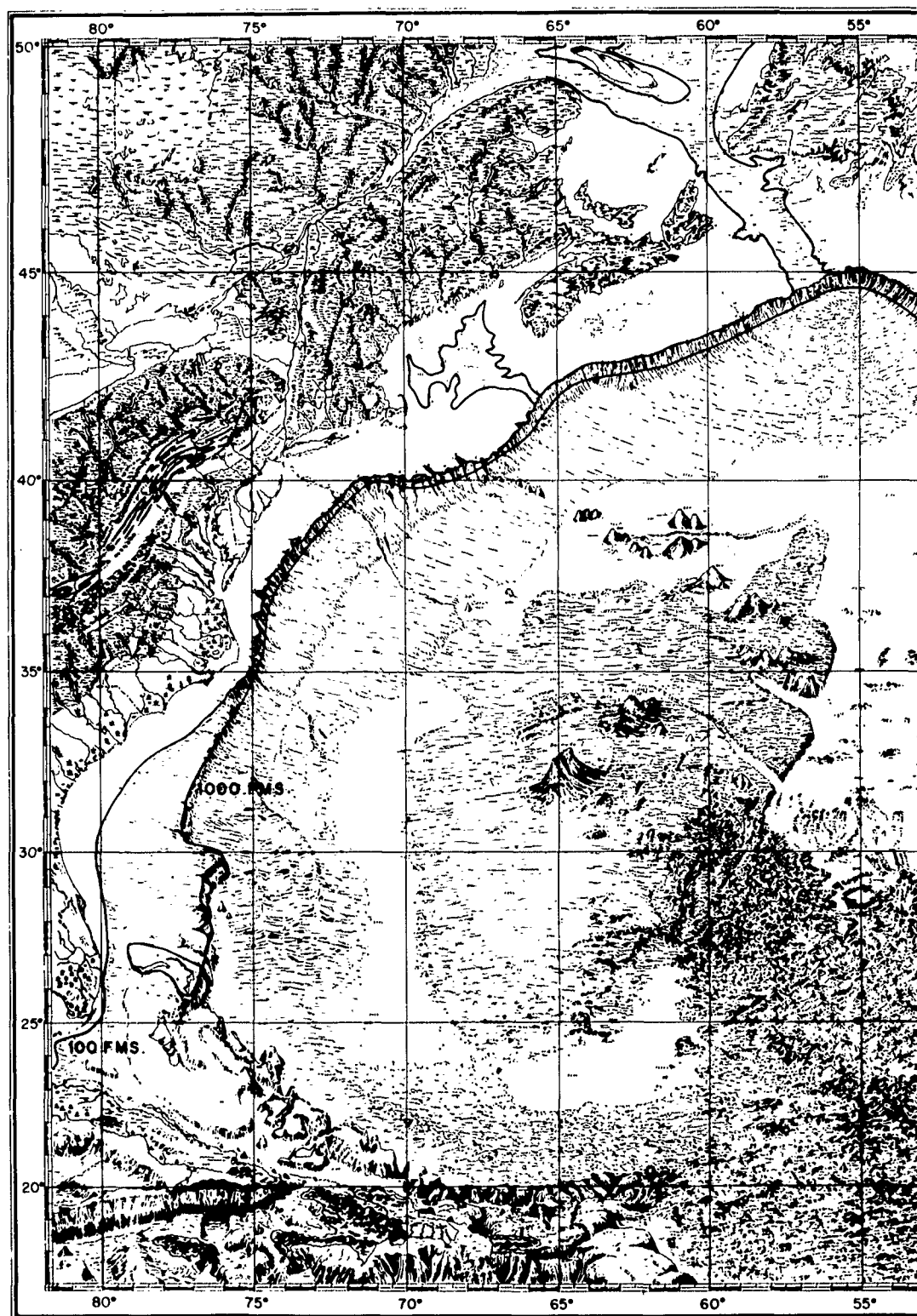


Figure 10 100 and 1,000 FATHOM CURVE IN THE NORTHWESTERN ATLANTIC (Courtesy of the Lamont Geological Observatory [Columbia University] Copyright 1957 Bruce C. Heezen)

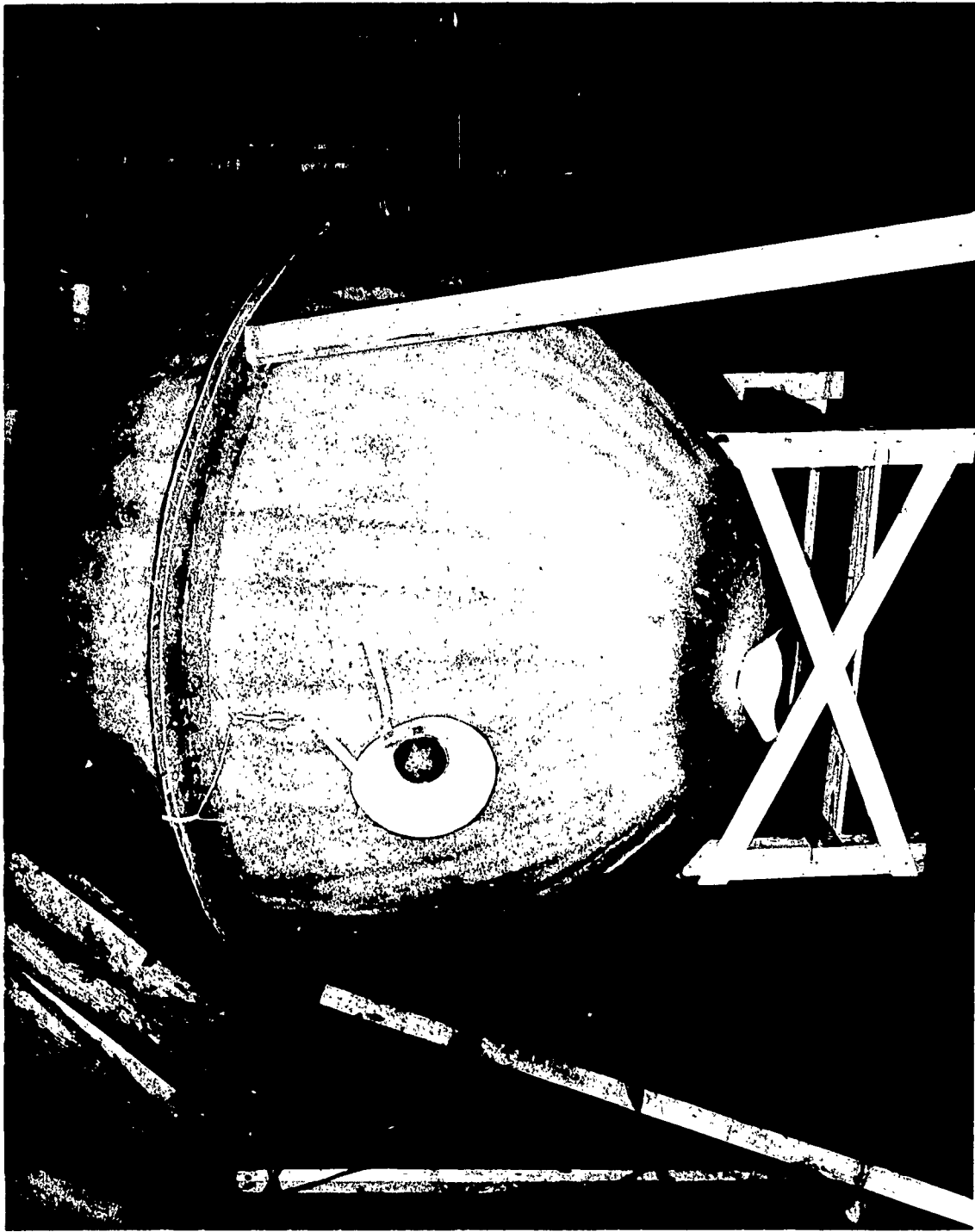


Figure 12 FULL SCALE FIBREGLAS MOCK-UP OF "ALVIN"
PRESSURE HULL

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A specification was prepared and proposals solicited from industry in May 1962 to design and construct a 6,000 foot research vehicle. Competitive bids were received and the vehicle contract was awarded to General Mills on 4 September 1962. The pressure hull structural analysis and the associated engineering details, the propulsion, and the trim and buoyancy systems have been the major problems studied. A hydrodynamic study is being conducted with a 1/12 scale model at MIT.

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